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REVIEW

Routine Measurement of Radioisotope Left Ventricular Ejection Fraction Prior to Vascular Surgery: Is it Worthwhile?

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Objective. *To determine whether estimation of left ventricular (LV) ejection fraction (EF) by means of multiple gated acquisition (MUGA) scanning could reliably stratify cardiac risk prior to elective major vascular surgery.*
Methods. *A review of the English-language literature.*
Results and Conclusions. *Twenty-two studies enrolling a total of 3096 patients were identified from 1984 to date. Selection bias, blinding of the results, different cut-off limits, and several retrospective studies were some of the problems preventing a comprehensive analysis. The resting LVEF was not found to be a consistent predictor of perioperative ischaemic cardiac events. In the perioperative phase, poor LV function was, mainly, predictive of congestive heart failure, and, in the long-term, of cardiac outcome. The presence of myocardial wall motion abnormalities was also associated with both a higher chance of postoperative cardiac complications and a worse long-term cardiac outcome. Although measurements of LV function seem to play a key role in defining a patient's long-term prognosis, the value of routinely measuring LVEF preoperatively is limited and, therefore, MUGA scanning cannot be recommended as a general screening test. Despite this, it has been widely used for cardiac risk assessment in vascular surgery, and only recently its popularity has started declining. Other tests, such as stress-echocardiography and myocardial perfusion imaging, used selectively in moderate-risk patients can refine prediction of cardiac risk. In the future, gated stress myocardial perfusion scintigraphy, perhaps combined with ANP/BNP plasma level determination, may become a first choice test in preoperative cardiac risk assessment.*

Key Words: Preoperative cardiac assessment; Cardiac risk prediction; Vascular surgery; Radionuclide ventriculography; Multiple gated acquisition scanning; Radioisotope left ventricular ejection fraction.

Introduction

Coronary artery disease (CAD) is the leading cause of morbidity and mortality after major vascular surgery. Such patients consume a relatively large proportion of health service resources and their preoperative assessment and perioperative care are common concerns for surgeons, anaesthetists, cardiologists, and physicians. Cardiac risk stratification is important because identification of individuals at increased risk may allow important alterations in perioperative management. In the preparation of a patient for elective major vascular surgery, a variety of testing modes are available. These range from simple clinical evaluations, through a variety of imaging, stress testing procedures, and electrocardiographic (ECG) analysis, to coronary angiography. Numerous studies have attempted to identify strategies for stratifying candidates for major vascular surgery, but, so far, none has gained universal acceptance.[1–3] Although nuclear cardiology offers sophisticated options of cardiac assessment, debate continues regarding the value of nuclear cardiac imaging prior to vascular surgery. Multiple gated acquisition (MUGA) scanning, in particular, has been used to assess cardiac function and stratify perioperative cardiac risk for more than two decades, its role, however, remains controversial. The aim of this study is to review the evidence concerning the role and the usefulness of MUGA scanning to predict cardiac risk prior to elective major vascular surgery.

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Methods

An English-language literature review was undertaken through to November 2003 to define the role of preoperative cardiac assessment using resting MUGA scanning prior to major elective vascular surgery. An electronic PubMed and Medline search was performed using the terms: 'noncardiac surgery' or 'vascular surgery', combined with 'coronary artery disease', 'cardiac assessment', 'cardiac risk prediction', 'cardiac risk stratification', 'perioperative care', 'postoperative complications', 'multiple gated acquisition scan', 'radionuclide ventriculography', 'radionuclide angiocardiography', 'radionuclide cardioangiography', 'radioisotope left ventricular ejection fraction', 'gated radionuclide angiography', 'gated heart blood pool scan', 'gated blood pool imaging', and 'gated pool ejection fraction'. References from the relevant articles were also searched. Studies comparing MUGA scanning to other functional cardiac tests, mainly review and meta-analysis articles were also identified. Selection of studies and data abstracting were performed independently by two of us (CDK, MSB) and discrepancies were resolved by consensus.

Results

Left ventricular ejection fraction (LVEF) is the single most important prognostic parameter in patients with CAD and many clinical management decisions are based on this.[4,5] Two-dimensional echocardiography, radionuclide ventriculography techniques, and contrast cineangiography are all equally acceptable methods of estimating LVEF. Echocardiography is noninvasive and usually adequate for the assessment of left ventricular (LV) performance, but has the disadvantage of being a much less accurate and more operator-dependent method. MUGA scanning is used less often these days because of the increase in echocardiography but remains the investigation of choice for the noninvasive quantification of LV function. When compared to echocardiography, radioisotope LVEF is both accurate and highly reproducible.[6–8] Therefore, when a precisely reproducible measurement is required for patient management decisions, MUGA scanning is the method of choice. This is recognised and radioisotope LVEF has been used extensively as a means of preoperative cardiac risk assessment. A study comparing radioisotope with echocardiographic LVEF found the correlation of LVEF determined by both methods to be good (Pearson correlation coefficient $r = 0.81$, SEE $= 3.5$) and so was intra- and inter-observer reproducibility.[7] Both the latter were better for radioisotope LVEF than echocardiographic LVEF. Clinically relevant differences did not occur on repeat processing of MUGA scanning, whereas potentially clinically relevant differences occurred in 8–26% of studies on repeat analysis of echocardiography.

A total of 24 studies looking at whether a resting radioisotope LVEF could predict adverse cardiac events in the postoperative period were identified in the English-language literature.[9–32] One repeat publication from the same institution with overlapping study periods,[31] and a further one, using the first-pass rather than the equilibrium ventriculography,[32] were excluded. This left 22 studies for analysis, with a total of 3096 patients from 1984 to date.[9–30]

There was significant heterogeneity between studies with regards to study design, patient selection, blinding of tests results, positivity criteria for the MUGA test, and definition of cardiac end points. A summary of the clinical characteristics of each study is presented in Table 1. These differences and the inconsistency in the reporting of the results presented several problems preventing a true meta-analysis of the subject. MUGA scanning may have been performed in consecutive patients presenting for surgery or in selected patients chosen according to clinical criteria. The predictive value of the scan is likely to be higher when selected patients are tested. Selection bias occurs because those deemed to be at higher risk on clinical grounds are more likely to get the test.[33] The predictive value of MUGA scanning is likely to be lower in unblinded studies, because patients with positive test results may undergo conservative operations, receive haemodynamic monitoring and stay longer in the intensive care unit.[24,33] Such care may decrease the rate of adverse cardiac outcome after surgery. Studies in which patients are recruited consecutively and physicians are blinded to the results are likely to provide a relatively unbiased predictive accuracy.[33] Additionally, different studies employed different statistical methods in analysing the results. Some examined LVEF as a continuous variable, whereas others as a dichotomous one. Some used univariate analysis, whereas others employed logistic regression. Another problem making studies noncomparable was the differences in the study populations as reflected by the wide variety of 'higher' risk noncardiac surgical operations included. Finally, another limitation is that the retrieved articles cover a time span of 20 years. No doubt, the quality of gamma cameras, radioisotopes and computer software has evolved and improved with time. Therefore, one should take into account the potential differences in

Table 1. Studies (in chronological order) which examined the prognostic value of radioisotope LVEF in predicting cardiac morbidity and mortality after different types of surgical procedures (Refs. 9–30)

Study (Ref. no.)	No. of patients	Type of study	Technique	Positivity criteria	Cardiac events (total pts)	Definition of cardiac endpoints	Association between LVEF and cardiac events	Type of surgery
Commin 1984[9]	34	Prospective	LAO and anterior plane	<50%	0(8)	All cardiac events	No	Aortic
		Unblinded	12 Images/projection, 500 heartbeats	≥50%	0(26)			
Pasternack 1984[10]	50	Retrospective	12 min	≤35%	4(5)	MI	Yes	AAA repair
		Unblinded	16-Interval gate	36–55%	4(20)			
				≥56%	0(25)			
Pasternack 1985[11]	100	Retrospective	12 min	≤35%	6(8)	MI	Yes	Lower limb revascularisation
		Unblinded	16-Interval gate	36–55%	8(42)			
				≥56%	0(50)			
Mosley 1985[12]	41	Prospective	LAO plane	<30%	3(4)	Cardiac death	Yes	Aortic
		Unblinded	16-Frame cycle (4–5 min)	>30%	1(37)			
Kazmers 1988[13]	73	NA	LAO, anterior and left lateral plane	≤35%	3(7)	MI, CHF and new ventricular arrhythmia	Yes	Carotid
				>35%	7(75)			
Lazor 1988[14]	196	Retrospective	NA	≤35%	8(41)	Cardiac death	Yes	Cardiac, vascular and general surgical
				36–54%	3(56)			
				≥55%	2(91)			
Kazmers 1988[15]	60	NA	LAO, anterior and left lateral plane	≤35%	1(10)	MI	No	AAA repair
				>35%	3(50)			
Franco 1989[16]	85	Retrospective	LAO, steep LAO and anterior plane	≤35%	3(15)	MI	No	Lower limb revascularisation
			1 mg stannous pyrophospate + 20 mCi of Tc99m pertechnetate (20 min) 28-interval gate, 4 million counts	36–55%	3(20)			
				≥56%	9(50)			
McCann 1989[17]	104	Retrospective	NA	≤35%	1(19)	Cardiac death	No	AAA repair
		Unblinded		>35%	2(85)			
Fletcher 1989[18]	72	Prospective	LAO, modified *in vivo* method, stannous pyrophosphat e injected iv; 900 MBq Tc99m, 24 frames on a 64 × 64 matrix, 4 million counts	≤35%	3(10)	All cause mortality	Yes	AAA repair
		Unblinded		>35%	0(62)			
				≤45%	5(16)	Cardiac failure		
				>45%	3(56)			

Table 1 Continued

Study (Ref. no.)	No. of patients	Type of study	Technique	Positivity criteria	Cardiac events (total pts)	Definition of cardiac endpoints	Association between LVEF and cardiac events	Type of surgery
Pedersen 1990[19]	95	Prospective		<50%	21(36)	Cardiopulmonary complications	Yes	Noncardiac
		Blinded	NA	≥50%	7(59)			
McPhail 1990[20]	85	Prospective	LAO and LPO views, *in vivo* method with 25 mCi of Tc99m	<50%	9(17)	Cardiac complications and death	No	Aortic
				≥50%	24(68)			
Matley 1991[21]	183	Prospective	Anterior, LAO and left lateral plane	≤50%	11(38)	Major cardiac events (MI, CHF and malignant ventricular arrhythmia)	Yes,* WMA	Aortic
		Unblinded		>50%	10(143)			
				≤45%	8(24)			
				>45%	13(157)			
				≥40%	6(17)			
				>40%	15(164)			
				≤35%	5(8)			
				>35%	16(173)			
Bunt 1992[22]	630	Prospective	NA	<35%	5(57)	MI	No†	Vascular
		Unblinded		≥35%	0(571)			
Louridas 1992[23]	131	Retrospective	NA	≤35%	2(11)	Cardiac death	No	Vascular
		Unblinded		36–54%	2(38)			
				≥55%	2(82)			
Baron‡ 1994[24]	457	Prospective	*In vitro* labelling of red cells	<50%	22(75)	Prolonged myocardial ischaemia, MI, CHF and ventricular arrhythmia	No	Aortic
		Unblinded	250 cycles (12 frames)	≥50%	64(382)			
Galland 1995[25]	48	Prospective	*In vivo* labelling, 700MBq Tc99m, 400 heartbeats	<35%	4(6)	All cardiac events (major and minor)	No	Aortic
		Unblinded		≥35%	13(42)			
Schueppert 1996[26]	394	Prospective	NA	<35%	1(24)	Nonfatal MI	No§	Vascular
		Unblinded		≥35%	7(339)			
Cohen‡ 1998[27]	104	Prospective	NA	NA	NA	All-cause mortality and complications	No	AAA repair
		Unblinded						
Heiba‡ 1999[28]	101	Unblinded	LAO, anterior and left lateral plane, 25–30 mCi Tc99m, 4–6 millions counts, 64 × 64 word matrix	<50%	12(42)	Major cardiac events (MI, pulmonary oedema and cardiac death)	No¶	Vascular
				≥50%	5(59)			
Mamode‡ 2001[29]	297	Prospective	40 and 75° LAO plane, 24 frame cycle	NA	NA	Cardiac death, MI, CHF, unstable angina and serious arrhythmias	No¶	Vascular
		Unblinded	3 mg pyrophosphate 600 MBq Tc99m					

Table 1 Continued

Study (Ref. no.)	No. of patients	Type of study	Technique	Positivity criteria	Cardiac events (total pts)	Definition of cardiac endpoints	Association between LVEF and cardiac events	Type of surgery
Karkos‡ 2003[30]	102	Retrospective	40° LAO plane, 600 MBq Tc99m, 16 frames, 64 × 64 computer matrix	≤50%	9(30)	All cardiac events (major and minor)	No, WMA	AAA repair
		Unblinded		>50%	8(72)			

NA, information not available; LAO, left anterior oblique; MI, myocardial infarction; CHF, congestive heart failure. WMA: studies that have also assessed the value of wall motion abnormalities in predicting cardiac risk.
*LVEF was a significant predictor of cardiac events in patients undergoing AAA repair but not in those undergoing aortoiliac reconstruction for occlusive disease.
†LVEF was a significant predictor of perioperative MI in patients undergoing infrapopliteal reconstruction but not in those undergoing aortic or carotid surgery. No patient with LVEF <50% underwent elective aortic reconstruction in this series.
‡Studies employing logistic regression analysis.
§LVEF was only predictive of late cardiac outcome.
¶Heiba *et al.* and Mamode *et al.* found a statistically significant relationship between LVEF and cardiac complications on univariate analysis, but not when using logistic regression analysis.

the techniques used in each study when interpreting the results.

Ejection fraction and postoperative ischaemic cardiac events

Studies looking at whether a resting radioisotope LVEF could predict adverse cardiac events in the postoperative period have produced conflicting results. Traditionally, patients with LV dysfunction, reflected by a decrease in LVEF, have been considered at high risk for postoperative cardiac complications. Indeed, eight studies, reporting on 810 patients, have shown that preoperative resting LVEF could predict postoperative myocardial events.[10–14,18,19,21] All these earlier studies employed univariate analysis and none have carried out adjusted analyses to account for correlation between risk factors. In contrast, the remaining fourteen studies failed to show a statistical association between preoperative resting LVEF and ischaemic cardiac complications. Only five of these studies have used logistic regression to test for associations between variables.[24,27–30]

The above data suggest that resting LVEF is not a *consistent* predictor of postoperative ischaemic cardiac complications. This is not surprising since the resting LVEF gives only a simple estimate of the systolic function of the LV under the existing loading conditions. Not infrequently, the ejection fraction may be normal in a heart with advanced CAD until the myocardium is stressed. Such patients may be high-risk, and as a result, a normal resting LVEF is by no means reassuring that a patient is at low risk for cardiac complications in the postoperative period. Similarly, resting LV function measured by echocardiography has not been found to be a consistent predictor of perioperative ischaemic events.[25,34] Some studies found it useful, others did not.[25,34–41] In a recent Vascular Anaesthesia Society audit of 933 patients undergoing nonemergency infrarenal aortic surgery throughout the British Isles, assessment of LV function by echocardiography was obtained in almost half of them.[35] The mortality rate in patients who had echocardiography was no different than those who did not (8.2% versus 6.5%, adjusted odds ratio 1.31 (95% confidence interval 0.79–2.18), $P = 0.29$). Additionally, in the echocardiography group, there was no significant difference in mortality rate between patients with good, impaired, and severely impaired LV function.

Ejection fraction and postoperative cardiac failure

Three studies documented that resting radioisotope

LVEF was predictive of postoperative LV failure.[18,21,24] Fletcher *et al*. found that a LVEF less than 45% was associated with a higher likelihood of postoperative LV failure,[18] whereas Baron *et al*. showed similar associations with a cut-off LVEF of 50%.[24] Similarly, Matley *et al*. demonstrated a consistent correlation between LVEF and postoperative cardiac failure/pulmonary oedema using several different cut-off points of LVEF (i.e. 50, 45, 40 and 35%).[21]

Ejection fraction and late cardiac outcome

Preoperative LVEF has also been shown to be associated with significantly reduced overall long-term survival after successful vascular surgery.[15,42] However, McCann and Wolfe found no such association in a group of patients undergoing abdominal aortic aneurysm repair and they concluded that patients should not be denied aneurysm resection solely on the basis of LVEF.[17] When considering patients with severely impaired LV function (LVEF of 35% or less), Kazmers *et al*. found that patients with an LVEF of 29% or less formed a subgroup at even greater survival disadvantage and recommended that surgery should be performed for only the most compelling indications.[43] These findings are hardly surprising, as several studies indicate that resting LVEF at the time of the initial evaluation is highly predictive of subsequent outcome in nonsurgical patients with CAD.[44–46] Of particular importance is that the relationship is not linear. Prognosis changes very little within the range of LVEFs from 45 to 65%; however, once LVEF drops below 40%, mortality increases exponentially.[45]

Ventricular wall motion abnormalities and postoperative cardiac complications

In addition to determination of LVEF, MUGA scanning can also show ventricular wall motion abnormalities (akinesis, hypokinesis, dyskinesis). These may be present at rest or with exercise. Only two studies have addressed the importance of myocardial wall motion abnormalities in predicting postoperative cardiac complications.[21,30] It appears that patients with wall abnormalities both with, or without an abnormal ejection fraction, are more likely to suffer a postoperative cardiac problem. A further study demonstrated that ventricular wall motion abnormalities were also associated with reduced overall survival after successful lower limb bypass surgery.[42] The association between wall motion abnormalities and adverse cardiac events is not unique to MUGA scanning. Myocardial wall motion abnormalities detected by resting transthoracic echocardiography are also predictive of perioperative cardiac complications.[36]

MUGA scanning as compared to other functional cardiac tests

Many would argue that other functional cardiac tests, such as the myocardial perfusion imaging and stress echocardiography, are superior to MUGA scanning in terms of predicting cardiac morbidity or death after major vascular surgery. Resting MUGA scan differs from myocardial perfusion imaging studies or stress echocardiography in that it measures the LVEF and detects wall motion abnormalities at rest. The latter studies are more invasive and use pharmacological stress to test for myocardial ischemia that is manifested as reversible or fixed perfusion defects and wall motion abnormalities. Considering abdominal aortic surgery, in particular, it has been suggested that stress tests are superior, as they may simulate, to a certain extent, the stress exerted upon the myocardium during crossclamping and declamping of the aorta.

Dipyridamole-thallium scanning (DTS) is the most extensively studied noninvasive approach to the cardiac risk stratification with a reversible perfusion defect generally found to be the most powerful covariable associated with perioperative cardiac events.[47–49] This has been shown to be highly sensitive for the detection of coronary stenoses. In addition, a negative test indicates a low risk for cardiac complications i.e. has a high negative predictive value. However, the frequent false-positive results particularly with single photo perfusion scintigraphy, is a major limitation of this test. Attenuation artefacts such as breast tissue and the diaphragm can produce apparent perfusion defects.[50] Normal scans significantly reduce the likelihood of perioperative cardiac complications, whereas patients with redistribution have a higher cardiac risk than those with a persistent perfusion defect.[47–49] There is an incremental increase in the probability of postoperative cardiac events with increasing size and number of reversible defects. Quantification of delayed redistribution is more predictive of cardiac death or myocardial infarction than simple dichotomous interpretation in positive/negative results. A recent meta-analysis confirmed that semiquantitative myocardial perfusion imaging could provide better estimates of perioperative risk than nonquantitative scintigraphy.[51] Reversible defects in less than 20% of myocardial segments do not significantly alter the risk of perioperative cardiac

complications, whereas greater extents reversibility increase the risk after noncardiac vascular surgery. Pooled data from 24 studies on 3354 patients undergoing vascular surgery indicate that DTS has sensitivity for the prediction of adverse perioperative cardiac events of 83% and a specificity of 49%.[50,52]

Stress echocardiography with dobutamine (DSE) or dipyridamole (DiSE) is an alternative stress test for vascular surgical candidates. Tissue harmonics has improved the accuracy of endocardial delineation and it will likely reduce intra- and inter-observer variability, which is one of the major limitations of the test.[50] Patients demonstrating extensive ischaemia under dobutamine stimulation (>5/16 LV segments involved), experience 10 times more cardiac events than patients with limited stress-induced ischaemia (<4 segments involved).[53] According to most meta-analyses, it offers the best prediction for perioperative events, with a negative predictive value close to 100% and a positive predictive value up to 38% among intermediate- and high-risk patients, even if it does not add discriminative power in patients with no clinical markers of CAD.[54]

There have been few comparisons of the various imaging techniques used for perioperative risk assessment. Comparing MUGA scanning with DTS, McPhail *et al*. found that although the two tests had a similar specificity, the latter was much more sensitive.[20] A further study from the same institution compared MUGA scanning, exercise ECG-testing, and DTS for the prediction of cardiac complications following vascular surgery. DTS, with the greatest sensitivity and predictive power, was the optimal initial test for identifying high-risk patients.[55] One meta-analysis of 20 studies looked at DTS, resting LVEF estimation by MUGA scanning, ischaemia monitoring by ambulatory ECG, and DSE, to determine which test was the most effective in predicting adverse cardiac outcome after vascular surgery. The data were not definitive in determining the optimal test because the confidence intervals overlapped, but DSE had the highest predictive value.[33] These observations were confirmed by two recent Dutch studies.[52,56] In the first, more than 2000 consecutive patients who underwent DSE, DiSE or DTS before major vascular surgery were studied.[56] Both stress echocardiography tests were equally effective in stratifying cardiac risk, whereas DTS had a significantly lower prognostic value. The second study was a meta-analysis of 58 published reports on 8119 vascular patients evaluating the predictive performance of six noninvasive tests used for perioperative cardiac risk stratification.[52] The authors compared the discriminatory value of ambulatory ECG, exercise-ECG, MUGA scanning, DSE, DiSE, and myocardial perfusion scintigraphy using an innovative meta-analytic approach. The accuracy of the tests was compared and presented using a summary receiver operating characteristic (ROC) curve, and the performance of individual test was corrected for selected patient and study characteristics. The study demonstrated that, compared to other modalities, DSE showed a positive trend towards a better diagnostic performance than the other tests, but this was only significant in the comparison with myocardial perfusion scintigraphy. It was suggested that DSE may be the favoured test in situations where there is valvular or LV dysfunction.

Exercise or stress MUGA scanning and cardiac risk prediction

It is likely that the addition of exercise or pharmacological stress will improve the predictive value of preoperative MUGA scanning. In the nonoperative setting, the finding of a major fall (>5%) in LVEF from rest to exercise carries with it poor prognosis in patients with CAD.[46,57–61] The ejection fraction at peak exercise, rather than its change with exercise may provide the most valuable prognostic information. Compared to coronary angiography, exercise MUGA scanning data could offer comparable prognostic information noninvasively.[57,59] LV function correlates well with the total extent of myocardial ischaemic burden, and has been shown to be a stronger predictor of prognosis than the coronary anatomy.[46,57] This is because the number of diseased coronary arteries is a fairly simplistic way of describing the extent of CAD and does not correlate with measured coronary flow reserve. Combined with clinical information, exercise radionuclide variables could predict accurately future events in patients with stable CAD or recent myocardial infarction, and act as surrogate for the catheterisation data.[46,57] In addition, the response to exercise before cardiac surgery is a major predictor of symptomatic outcome after coronary artery bypass grafting.[62] However, the only study to examine the role of stress MUGA scanning prior to noncardiac surgery found that only peak workload, and not indices of left ventricular function, predicted perioperative cardiovascular events.[63]

Combined myocardial function and perfusion data and cardiac risk prediction

Few studies have examined the additive values of LV performance at rest and myocardial perfusion in predicting perioperative cardiac risk. Use of the

combination of MUGA scanning and myocardial perfusion imaging has been shown to improve cardiac stratification as both abnormal radioisotope LVEF and extent of ischaemic myocardium have independent and complementary predictive power for cardiac events in patients undergoing vascular surgery.[28] Similarly, the combination of resting echocardiography and dipyridamole-thallium scintigraphy can improve the identification of patients at risk for perioperative cardiac complications.[37] Today, with the advent of nuclear cardiology, ECG-gated single photon emission computed tomography (ECG-gated SPECT) offers combined assessment of both myocardial perfusion and LV function (including LVEF and volumes) and emerges as a useful adjunct in the cardiac assessment of high-risk patients with cardiovascular disease.[64] Whether this would be the 'ideal' screening test prior to major noncardiac surgery remains to be seen.

Combined clinical and radioisotope data and cardiac risk prediction

Instead of testing all candidates for major vascular surgery indiscriminately, many surgeons adopt a Bayesian approach and use clinical criteria to select patients for further cardiac testing.[65] This has been shown to refine preoperative risk stratification. A typical example is the use of Eagle criteria to select candidates for myocardial perfusion imaging.[66] Five clinical variables were identified: diabetes, age > 70 years, Q-wave on ECG, angina, and history of ventricular ectopic activity. In patients at intermediate risk (one or two clinical predictors), thallium redistribution could further optimise the cardiac risk prediction, whereas in those at high (three or more risk factors) or low risk (no risk factors), DTS could offer no additional stratification over clinical information alone. Similarly, Venzetto *et al*. showed that the addition of the results of DTS to clinical data significantly increased the ability to predict a perioperative cardiac event.[67] Recently, Poldermans *et al*. used DSE to further stratify patients judged as being high risk according to similar clinical criteria.[68] The role of resting echocardiography, however, is controversial. Halm *et al*. found that resting echocardiographic variables added little discriminative information to the clinical data in patients having noncardiac surgery.[40] It is likely that preoperative transthoracic echocardiography can provide independent information about the risk of postoperative cardiac complications in selected patients only. Rohde *et al*. showed that echocardiographic data other than resting LVEF, including LV function, hypertrophy indexes, and Doppler-derived measurements, could provide significant incremental information for patients at increased risk for cardiac complications by clinical criteria, but not in otherwise low-risk patients.[36] To date only two studies have examined whether the combination of clinical criteria and MUGA scanning could optimise the prediction of postoperative cardiac events.[25,31] The most recent one applied the new, modified version of the original Goldman index, the Revised Cardiac Risk Index in patients undergoing abdominal aortic surgery.[31] The index included the following six risk factors: high-risk type of surgery, known history of ischaemic heart disease, congestive heart failure, previous stroke or transient ischaemic attack, insulin-dependent diabetes, and creatinine level more than 2 mg/dl (177 μmol/l). MUGA scanning could further stratify cardiac risk only in those considered by the index to be at high risk, i.e. those with two or more risk factors. This meant that preoperative MUGA scanning was unnecessary in low-risk patients, i.e. in approximately one-fifth of patients in that series. In contrast, an earlier study comparing the Detsky modification of the original Goldman Index with MUGA scan data found no correlation between the two.[25]

Combined biochemical and radioisotope data and cardiac risk prediction

Recently, a number of circulating factors have received close attention as cardiovascular markers that reflect LV function and/or predict cardiovascular prognosis in a spectrum of cardiac disease ranging from severe heart failure from different causes to asymptomatic ischaemic LV impairment.[69,70] Plasma atrial natriuretic peptide (ANP) and B-type natriuretic peptide (BNP) (otherwise known as brain natriuretic peptide), their precursors N-terminal proAtrial (N-ANP) and N-terminal pro-Brain natriuretic peptides (N-BNP), catecholamines, renin, and aldosterone have all been investigated as potential predictors of cardiac function.[69–73] Amongst them, BNP and N-BNP are, probably, the strongest markers for LV dimensions and LVEF in patients with systolic LV dysfunction.[70–73] High concentrations are very well correlated to low LVEF values. This is an area of intense research in cardiology, but as yet, no studies have addressed the value of these peptides in cardiac risk stratification prior to vascular surgery. Although work is still ongoing, simple blood tests, such as plasma N-BNP and BNP measurements may be used in the future to screen patients with suspected ventricular dysfunction

and one of these could reasonably be included in the routine clinical work-up of vascular surgical candidates to reduce the demand for further cardiac investigations.

Discussion

The best way to identify patients who are at risk of perioperative cardiac complications after major vascular surgery and who might benefit from further cardiac testing, alternative cardiac strategies, or preliminary myocardial revascularisation has yet to be defined. A negative preoperative test in a particular patient, although reassuring for the surgeon and the anaesthetist, does not mean that cardiac complications are excluded. Perioperative myocardial infarction is a complex entity, which can be precipitated by a number of different pathophysiologic mechanisms, including increases in myocardial oxygen consumption, prolonged sympathetic stimulation and tachycardia, increased vasomotor tone, hypercoagulability, potential atheromatous plaque rupture leading to thrombus formation, hypothermia, and blood loss.[54] Currently, there is no single test that adequately mimics all these factors. Moreover, the culprit lesion causing myocardial infarction often occurs in a insignificantly stenosed coronary artery.

The value of MUGA scanning for predicting perioperative cardiac events has been assessed by many studies.[9–32] However, the increasing use of echocardiography and the substantial increase of myocardial perfusion imaging over the last decade has led to a fall in the popularity of MUGA scanning. In 1998, a British Nuclear Cardiology Society survey showed that radionuclide ventriculography use had fallen in the UK by 47%.[74] Nevertheless, it remains the method of choice where reproducibility or accuracy is a critical issue, such as in cancer chemotherapy or major cardiovascular research studies.[75,76] Data on current practice in the preoperative cardiac risk stratification of patients having major vascular surgery show MUGA scan to be the second most popular preoperative cardiac test amongst surgeons and anaesthetists in the UK.[2,3] Although the utilisation rate varies considerably, 13–19% of the vascular units in the UK, and 39% of those to which the investigation is available, use MUGA scan as the investigation of choice. In the USA, where a much greater utilisation of cardiological investigation is taking place, preoperative radioisotope LVEF is estimated in 33% of cases.[1]

According to the current practice guidelines published by the American College of Cardiology/American Heart Association (ACC/AHA) and the American College of Physicians, routine noninvasive evaluation of LV function prior to elective major noncardiac surgery is of limited value.[77–79] Furthermore, a comprehensive meta-analysis recently showed that a low LVEF has a relatively poor sensitivity, a high specificity, and no significantly better predictive performance than other cardiac tests.[52] The authors suggest that the observed limitations may be explained by the failure of the test to detect severe underlying CAD, changes in predictive value over time and improved anaesthetic and surgical perioperative care. Thus, MUGA scanning may not be suitable for preoperative cardiac risk stratification. This carries important implications considering that as much as 80% of the vascular anaesthetists in the UK employ some form of LVEF measurement (echocardiographic or radioisotope) as the initial cardiac test prior to vascular surgery.[3] The ACC/AHA guidelines have adopted a stepwise approach in the perioperative cardiac evaluation. Low and high-risk patients should be best identified on the basis of clinical markers. In those with intermediate risk as judged by clinical evaluation, other tests, such as the stress echocardiography or myocardial perfusion imaging can further stratify risk. The proposed algorithms, based on evidence from cohort studies and expert opinion, appear to be effective in both stratifying cardiac risk, and reducing resource use and costs without affecting outcome.[80–82] Ideally, these recommendations should be prospectively validated by randomised clinical trials, however, no such trials have been published over the past six years.[82]

In conclusion, although resting MUGA scanning seems to be useful in cardiac risk stratification and the overall risk-versus-benefit assessment of candidates for major vascular surgery, its role in predicting accurately perioperative ischaemic cardiac events is inherently limited. Resting LVEF is a static measure of cardiac function and unless very low may give little information about how the heart performs under stress. A low ejection fraction is mainly predictive of post-operative cardiac failure and long-term survival. Routine measurement of radioisotope LVEF prior to major vascular surgery is, therefore, not necessary, unless there are specific indications similar to those in the nonoperative setting, for example patients with current or poorly controlled congestive heart failure, and, less so, patients with previous congestive heart failure or those with dyspnoea of unknown aetiology. Whatever the overall value of preoperative LVEF, similar information can be gained by echocardiography at less cost and with no radiation risk.

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